Modeling Active and Passive Microwave Remote Sensing of Multilayer Dry Snow using a Coupled Snow Hydrology-Microwave Model

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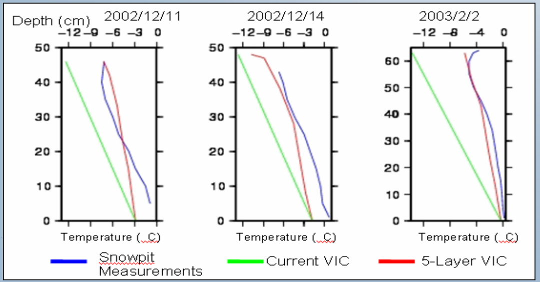
Abstract

This poster illustrates our work in the physical theory of the active and passive remote sensing. We use the same physical dense media radiative transfer (DMRT) model for predicting the microwave signatures of both backscattering coefficients and brightness temperatures. NASA is considering the Snow and Cold Land Processes (SCLP) mission that will provide the first high-resolution global sampling of snow water storage to explore its variability and effect in the global water cycle. The mission uses the dual high-frequency radar (X-, Ku) measurements and dual high-frequency radiometer (K-, Ka) measurement. At the same time, the COld REgions Hydrology High-resolution Observatory (CoReH2O) mission is being considered by the European Space Agency (ESA) with the objective to improve the modeling and prediction of water balance and stream flow , water and energy cycles at high latitudes, and the relation to climate change and variability. The mission employs twin frequency synthetic aperture radars (9.6 and 17.2 GHz). Our physical models are very important in the data assimilation.

Hydrology Model – VIC

VIC is a macro scale hydrology model that essentially solves the energy and water balance over a girded domain. It is distinguished from other land surface models by the parameterization of sub-grid variability of soil moisture, precipitation, topography and vegetation. The snow modeling component consists of a multiple layer formulation that build on a number of existing models. The purpose of the model is to build an adequately complex model that is computationally efficient and able to accurately reproduce both the horizontal and vertical variability of snowpacks at the spatial scales of interest. The maximum number of layers in the modeled snowpack is a user-defined input in order to accommodate for different simulation scenarios. Each time there is new snowfall a new layer is added on top of the snowpack. The model then solves the snowpack energy balance as a set of nonlinear equations. The following figure shows snowpack temperature profiles at the LSOS site (from CLPX), simulated by 1-layer and 5-layer VIC as well as the observed one.

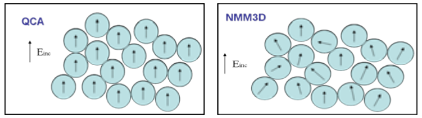


Microwave Model – QCA/DMRT and NMM3D/DMRT

The dense media radiative transfer (DMRT) theory has been applied in studying both passive and active microwave remote sensing signatures [1], [2]. Because snow is a dense media in which the ice particles lie in close proximity of each other, the particles do not scatter independently. The DMRT theory takes into account the collective scattering effects of the particles by including the wave interactions among the particles. We couple the DMRT with the multilayer Variable Infiltration capacity (VIC) by using snow parameters that are predicted by VIC in the DMRT.

QCA (Quasi-Crystalline Approximation)

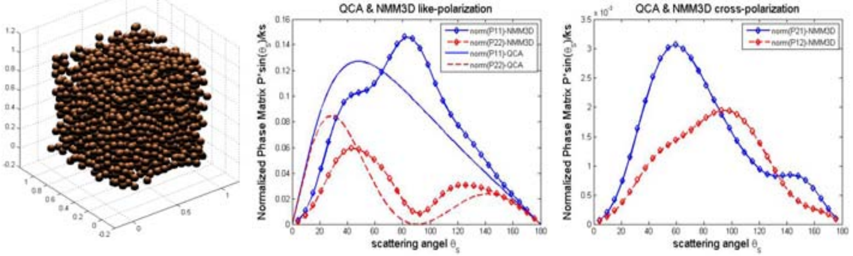
QCA is used in the Dyson equation for the coherent field and the correlated ladder approximation is used for the Bethe Salpeter equation for the incoherent field



NMM3D (Numerical Maxwell Model of 3-D simulation)

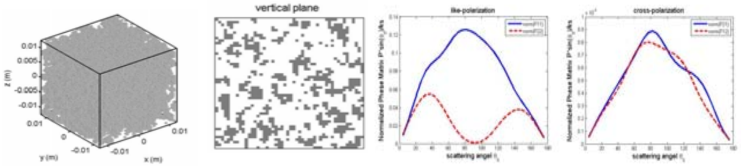
The position of the particles are generated by random shuffling and bonding. The concentration of the particles can be up to 40%. Maxwell Equations in forms of Foldy-Lax multiple- scattering equations are solved numerically.

Comparison between QCA and NMM3D
(1) The final induced dipoles are not aligned with incident field because of the near field interactions.
(2) The cross-polarization in the phase matrix is non-zero, which provides more cross polarization backscattering



Bi-continuous

The bi-continuous random structure is generated by discrete maps of continuous stochastic standing waves. The random wave number and random constant phase can be attain from proper distribution. Scattering problem can be solved by Discrete Dipole Approximation and fast algorithm CG-FFT is used. Sample size, sample discretization and number of samples have been tested.

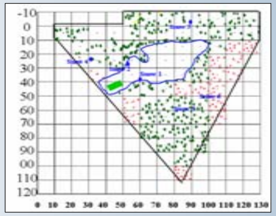


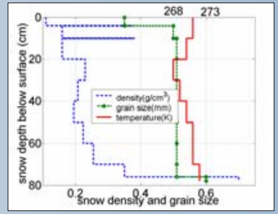
Multi - Layered DMRT

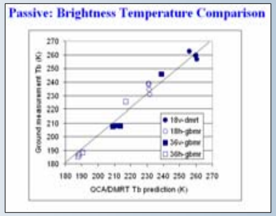
After getting the phase matrix and extinction coefficient from above models, we solve the dense media radiative transfer equation for layered snow. The specific intensity in the equation is decomposed as a sum of the reduced intensity and diffuse intensity. The reduced intensities in every layer can be solved analytically. The diffuse intensities are decomposed into Fourier series in the azimuthal direction, and then using the eigen-quadrature approach solves every harmonic. We consider full multiple scattering effects with 16 Gaussian quadrature angles. The same 16 angles are used in every layer.

Comparison with Ground Measurement

The model is applied to compare with measurements from the Cold-Land Processes Field Experiment CLPX Ground-based Microwave Radiometer (GBMR). We illustrate the model simulation of brightness temperature at 18GHz and 36GHz for different multi-layer snowpack structures. The snow thickness, densities and grain sizes vary among different layers. Vertical profiles of snow properties needed to drive the model were simulated by the newly developed multilayer VIC snowpack model. For the active data, our simulation data agree with both airborne polarimetric scanning radiometer (PSR) and airborne polarimetric Ku-band scatterometer (POLSCAT) data at Fool-Creek, Fraser.







Conclusion

In this study we evaluated a coupled snow hydrology (Variable Infiltration Capacity, VIC) and microwave emission (Dense Media Radiative Transfer, DMRT) model . The effect of multilayer has been accounted in both models to simulate the snow structure. With the same set of multi-layer snowpack profile, the coupled VIC and QCA/DMRT model are shown to agree with co-polarization backscattering coefficients and all 4 channels of brightness temperature observations simultaneously at LSOS.

Bibliography

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